TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 148

THE FLEXIBLE MOUNTING OF AN AIRPLANE ENGINE.

By K. Kutzbach

From Technische Berichte, Volume III, Part 4.

July, 1923

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE NO. 148

THE FLEXIBLE MOUNTING OF AN AIRPLANE ENGINE.*

By K. Kutzbach.

This paper deals with the suggested installation, of the "unbalanced" 8-cylinder Vee - engine (e.g. B_z III b, Kg III, D III b), in that a flexible mounting be used instead of bolting the engine rigidly to the airplane structure ; the idea being that the flexible mounting would be so adapted that the vibrations due to inertia effects would, as it were, "damp themselves out." In order to be able to judge of the practical feasibility of this proposal, it is first necessary to possess a clear idea of the forces which are set up and the movements which take place in an airplane engine.

Vibrations due purely to inertia effects, only manifest themselves when the engine is driven by an electric motor (which for convenience, is coupled to the engine instead of the airscrew) the engine being suspended on long elastic cords and operating without compression. In this case, with a four-cylinder engine we would have free oscillation of the entire engine, the period of vibration being at the rate of twice the speeddof revolution of

*From Technische Berichte, Vol. III, Part 6, pp. 205-7. (Paper read before the Conference of Airplane Designers at Adlershof, August 23, 1918).

of the engine, the oscillations being parallel to the plane passing through the axes of the cylinders. In the case of an 8-cylinder engine (Vee type), consisting of two four-cylinder engines with the cylinders set at an angle of 90°, these oscillations combine to produce horizontal transverse oscillations, since the vertical components of the vibrations, due to the two separate sets of cylinders, neutralize one another. If the amplitude of the movement of the crankcase is ascertained, it will be found that, for example, in the Hispano-Suiza engine, at a speed of 2000 R.P.M., there are 4000 transverse vibrations per minute with a displacement of only 0.25 mm.(.01 in.) while, in the Bz III b engine, there is a displacement of about 0.3 mm. (.012 in.). These small oscillations can be absorbed without difficulty by the employment of weak springs or similar contrivances, so that hardly any effect of the transverse vibrations, due to the inertia of the reciprocating parts, is imparted to the airplane; while at the same time the propeller thrust and torque are entirely taken up. It is, therefore, only necessary to preclude any possibility of resonance due to these transverse vibrations within the range of the engine speed met with in operation, say 300 to 2000 R.P.M. For this purpose it is sufficient, if the transverse vibrations are kept below 300 per minute, which can be easily accomplished by suspending the engine freely by means of straps several centimetres in length. A certain amount of transverse damping, which could be obtained

by the use of felt packing or by employing frictional devices, would still be required, owing to the vibrations that would be produced in a bank.

In this case, we have to reckon not only with variable transverse forces, but also with the bodily movement of the entire engine, when so mounted, on account of the variation in the gyroscopic effect of the two-bladed propeller when the airplane is banking. This latter action is similar to that of a weight mounted eccentrically on the crankshaft and rotating at twice the engine speed, the effects produced by it becoming more marked as the sharpness of the bank increases. Only propellers with more than two blades may be regarded as reasonably free from the effects of such vibrations in banks.

The pitching or "see-saw" movement of a badly balanced 6-cylinder engine can also be easily calculated. The Engine Testing Department tested a 6-cylinder Bz IV engine, which had its three forward pistons made of aluminum, and the three rear pistons of cast iron, each of the former weighing 2.65 kg. (5.84 lb.), and each of the latter 3.62 kg. (7.98 lb.). Tests on a spring-supported test-bench revealed no difference in the amount of vibration, as compared with a normal engine, the 8-cylinder Vee type, also showed no variation from other balanced types. Calculation shows that the pitching movement, at a distance of 500 mm. (19.7 in.) from the center of gravity of the Bz IV engine, with cast iron and aluminum pistons arranged as

above, the engine being run freely suspended, was only 0.5 mm. (0.02 in.). This small movement could also be easily taken up by a suitable light spring device. However, with this form of pendulum or spring mounting, the pilot would be cognizant of the fact that there are other factors, besides inertia, that may give rise to forces which operate detrimentally upon the airplane, since the effect of irregular cylinder pressure and the torque variation in the engine can produce much greater and more objectionable results than the effects of inertia alone.

This fact can be observed, at any time, on testing-stands fitted with spring suspension for the engine, as for example, those at Adlershof. There, the engine can be seen to be under strong vibratory action and the vibrations may be felt on the bench, particularly at low revolution speeds, when the effect of misfires and preignition is very marked. Inngeneral, each late or premature ignition, each irregularity in the functioning of the two carbureters of a 6-cylinder engine, in the timing of the valves and the ignition in the individual cylinders, and in the distribution of the mixture, is shown by the irregularity in the running of the engine. The torsional oscillations of the crank-case, and that of the crankshaft are inversely proportional to the moments of inertia of these parts about their axis of rotation. If the crankcase is not rigidly attached to the airplane, its moment of inertia is only about ten times that of the crankshaft, including the propeller. If then, the amount of the relative movement of the crankshaft is 3.6° with a fluctuation

in speed of $\delta = \frac{1}{100}$, the angular movement of the crankcase is approximately 0.36°, corresponding to a displacement of over 3 mm. (.12 in.) at a distance of 50 cm. (19.7 in.) from the axis of the crankshaft. As to be expected, misfires are productive of marked vibrations in the crankcase, when mounted on a spring test-bench, as well as on an airplane, and the effects of irregular engine speed can only be obviated by increasing the number of cylinders, since the employment of flywheels, is undesirable.

The employment of a spring mounting would undoubtedly reduce the torsional oscillation of the engine to a certain extent, and prevent it from extending to the structure of the airplane. In that event, the normal engine vibrations would reach their maximum magnitude and the valuable steadying influence of the inertia of the fuselage could not be utilized to minimize their effects. This arrangement would also be detrimental to the piping and other connections between the engine and the airplane.

Lastly, it should be borne in mind that the principal troubles in airplanes occur, primarily, in connection with resonance of the the individual parts. These parts may, however, still oscillate together without detrimental effects when the amplitude of the motion is sufficiently diminished by the use of springs. The prime necessity, therefore, is to preclude all possibility of resonance, within the range of the

normal R.P.M. of the propeller, by the adoption of appropriate methods of stiffening, strengthening or lightening of the structure. This should be the first consideration in designing new types.

To summarize, it may be said that a flexible connection between the engine and the airplane is probably possible, that this diminishes, primarily, the vibrations due to inertia, and, to a lesser degree, those due to the influence of torque variation. It is, however, far more important to eliminate all possibility of resonance in the airplane. It may, also, be added that the engine vibrates more when freely suspended than when rigidly mounted, this vibration having a detrimental effect on all connections between the engine and the airplane. Therefore, in view of the relatively insignificant advantages which may be derived from the elastic suspension of the engine, the present rigid mounting is to be preferred. This can only be improved by incorporating in the fuselage as many of the rigid airplane parts as possible.